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MICROWAVE AUGMENTED FREEZE-DRYING - FOUR STUDIES

by

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and
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In order to study the effects of microwave-augmented freeze drying on food quality and drying time, frozen peas and green beans as well a raw ground beef were freeze dried both conventionally and with microwave augmentation. Instrumental quality analyses, including rehydration ration, color, and shear force, in addition to sensory tests were performed on the dried and rehydrated products. It was found the use of microwaves greatly decreases the drying time with little or no quality loss.

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PREFACE

The information in this report is based on four different studies that were done using a microwave augmented freeze-dryer. The products studied were vegetables, peas and green beans, as well as raw ground beef. The products were freeze-dried in the same equipment both conventionally and using microwaves

Data contained in the report was presented at the 52nd and 53rd Annual Meetings of the Institute of Food Technologists, 1992 and 1993, New Orleans, LA and Chicago, IL, as well as at the 1992 International Drying Conference, Montreal, PQ, Canada.

We would like to thank Ms. Margaret Robertson of the Biohazards and Control Branch, Technology Acquisition Division, Sustainability Directorate, Natick RD&E Center for doing the proximate analyses of the various products.

Citation of trade names in this report does not constitute an official endorsement of the product.

MICROWAVE AUGMENTED FREEZE-DRYING - FOUR STUDIES

INTRODUCTION

Freeze-drying provides an alternative to other drying methods for foods that can be damaged by exposure to elevated temperature. A number of authors (Decareau, 1970; Ang et al., 1977; Rosenberg and Bogl, 1987) have shown that there is little or no loss in sensory qualities when freeze-drying is used.

However, conventional freeze-drying (CD) is a slow and expensive process. Four potential rate-limiting steps have been identified (Ang et al., 1977). They are (1) external heat transfer to the outer surface of the material from the heat source (2) internal heat transfer within the material (3) external mass transfer of water vapor from the surface, and (40 internal mass transfer within the material. During the drying cycle the thickness of the dried layer increases (steps 2 and 4 increase in importance) thus slowing down the sublimation rate so that conventional freeze-drying becomes expensive for commercial use.

The use of a volumetric heating mode in place of or in combination with the conventional surface heating source can greatly decrease the drying time (Ma and Peltre, 1975). Since microwave augmented (MW) freeze-drying is such a mode, it has the potential for increasing the drying rates by as much as an order of magnitude. A decrease in drying time by a factor of 3 to 13 has been reported (Hoover et al., 1966 and Ma and Peltre, 1975). It has also been reported that MW transport gives great advantages where the heat transfer is the limiting mechanism for transport (Yang and Altallah, 1985). However the advantages may be offset by higher energy requirements and capital costs (Peltre et al., 1977)

There have been few industrial MW applications because of the lack of good models for the coupling of heat and mass transfer (Ofoli and Komolprasert, 1988). Other problems that limit the use of MW augmented freeze-drying include corona discharge, nonuniform heating of the product, mismatch of impedance, inefficiency of the applicator, formation of aerosols and crystals (Arsem and Ma, 1985). Another potential problem, that of nonuniformity of drying within the MW drying chamber, has been observed (Peltre et al., 1977; Datta and Hu, 1992).

Many studies have addressed the MW augmented freeze-drying of real or model foods and other biological materials (Sandall et al., 1967; Decareau, 1970; Slater, . 1975; Yang and Altallah, 1985; Gibert and Boaeh-Ocansey,. 1985, Arsem and Ma, 185; Kitabatake et al., 1989). Others have compared several methods of processing (freeze-drying and conventional) to evaluate quality and/or cost factors. (Yang and Altallah, 1985; Kitabatake et al., 1989).

Freeze-drying has a unique application for military ration preparation, i.e., compression of partially dried foods. Compressed dehydrated foods offer advantages in space savings, a characteristic very critical for individual soldiers on their missions. Rahman et al. (1970) prepared blueberries and cherries with significant volume reduction while still maintaining their rehydrability, appearance, flavor and texture on reconstitution. However, the process was expensive. It involved freeze-drying of the fruits to a moisture content of less than 2%, then subjecting them to dry heat in an oven at 93.3°C for 10 minutes. The fruit became

thermoplastic and compressible to 12 to 14% of the initial volume. The overall reduction in volume can be 12 to 13 fold when compared to that of the loose frozen fruit. For nonfruit products, the dry foods (2% moisture) were wetted or misted by steam injection to raise the moisture level to 12 to 16% and thus render them plastic before compression and the subsequent final freeze-drying. The high cost of production has limited the variety and availability of the type of foods.

The objective of this research is to utilize microwave energy to remove the moisture expeditiously and uniformly and assess quality by various instrumental and sensory panel studies. Compression can likely take place at 12 to 16% moisture without damage to the structure of the food. Another objective is to develop an intermediate moisture product directly from the process that would serve as a shelf-stable ration component. Therefore, uniformity of moisture removal is extremely critical to insure that the food is microbiologically stable.

This report presents the results of four studies that were conducted in the general area of MW augmented freeze-drying.

METHODS

The investigations undertaken are reported for four food product groups studied.

A. Peas were freeze-dried, both conventionally (CD) and with microwaves (MW), at different levels of power input and total mass in the drying chamber. The sensory panel's study is also included for this work.

B. Peas and green beans were freeze-dried using different combinations of CD and MW techniques during different portions of the drying cycle.

C. Raw ground beef of different fat content and grind sizes were both MW and CD freeze-dried at the same processing conditions.

D. Peas and green beans were freeze-dried at different processing conditions and the mass of the partially dried product was measured at 12 positions in the drying chamber at various points of the drying cycle to determine the uniformity of the drying rate.

Drying

Drying rate measurements were conducted on the mass bulk of the product during each study. A Cober Electronics™ microwave freeze-dryer was used to perform the drying for all the studies. (Conventional freeze-drying (CD) refers to freeze-drying with this equipment without the use of microwaves.) A schematic drawing that illustrates the equipment components is shown in Figure 1. It has three drying trays, each 53.3 x 50.8 cm in dimensions. Each tray was split in half lengthwise with a partition to give two positions. The positions were: A - top tray, left side; B - top tray, right side; C - bottom tray, left side; D - bottom tray, right side. The trays were placed directly over each other, 15 cm apart. The top tray was not used in any of the studies. The radiant heating platens are controllable in the range of 21 to 121 ^{o}C. This platen system was used to provide CD drying. The microwave power is 2,450 MHz and is controllable within the range of 0 to 3.0 kW. The dryer is capable of controlling the vacuum level in the range of 7.0 to 4,000 Pa. Heat was applied to the platen under the tray, as well as the platen directly over the drying

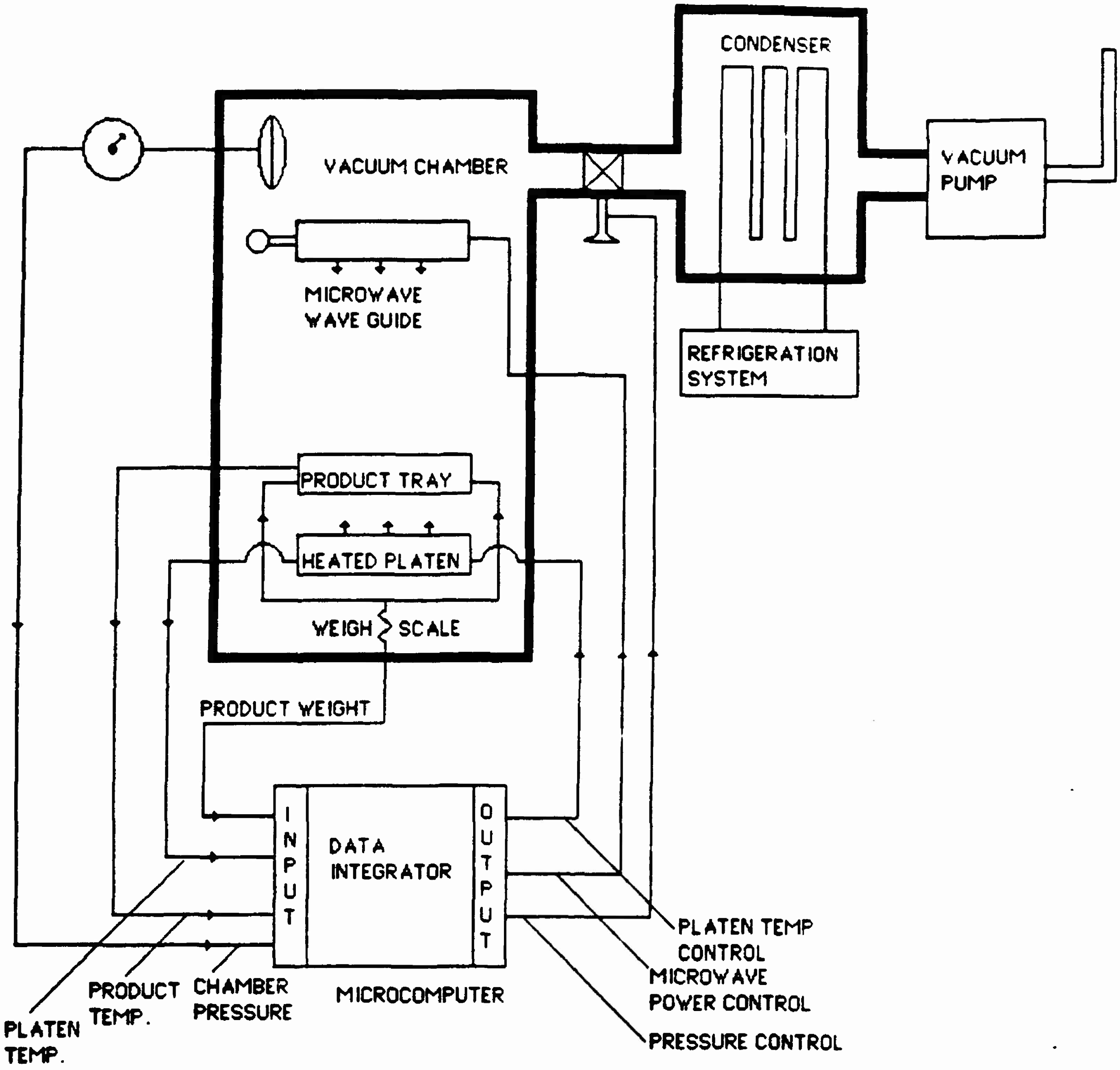

FIG. 1 - SCHEMATIC DIAGRAM OF MICROWAVE FREEZE-DRYER

tray. A temperature of 66 ^{o}C was maintained on both platens.

The drying rate was continuously monitored by a scale that measured the change in mass of the lowest tray. These data were recorded at five minute intervals with a Kay Instruments Digistrip III™ Recorder that had the capability of determining 5 g (0.01 lb) increments. During a drying run the vacuum within the chamber changed from an initial value of 20 Pa to a final value of 7 Pa.

Rehydration Ratio

The rehydration ratio is defined as the ratio of the increase in mass divided by the initial mass. Various instrumental studies were made on the rehydrated products to determine quality differences. The product to be measured was placed in 600 to 900 cm^3 of boiling water. It was continuously stirred for two minutes while in the boiling water. The water was then drained off through a No. 150 mesh metal screen, the product cooled and the mass of the drained product measured.

Shear Force

Either an FTC (Kramer) Shear Press, Model TP-4C™ or an SMS-TAXT2 Texturometer™ was used for these measurements. The exact method was tailored to the shape of the product. These measurements were made on the rehydrated vegetables.

Color Measurement

A Pacific Systems Spectrogard Reflectometer, Model 96™ was used for these measurements, which were also made on the rehydrated vegetables. A 3.3 cm thick glass cell was used to hold the samples being measured. A single reading was taken on each side of the cell through an aperture of 0.5 cm^2. Hunter "L", "a", and "b" measurements were made.

A greater "L" value indicates a lighter color. A greater negative "a" value indicates more red, less green. A greater "b" value indicates more yellow, less blue.

Proximate Analyses

The moisture for the vegetables was determined with a Computrac Max-50™ moisture analyzer. Moisture and fat for the ground beef was determined with standard AOAC methods (1990). Protein for the ground beef is estimated by difference as there is essentially no carbohydrate or ash in the meat.

Sensory Evaluation

Sensory evaluation was done only with study A. (Since there was no significant difference shown among the different processing conditions, it was felt that sensory evaluation of the green beans was unnecessary. The peas were rehydrated and brought to room temperature, approximately 21 ^{o}C. They were presented, with the undried control (frozen peas that that been thawed and brought to room temperature) to a 12-member panel for the rating of appearance, flavor, aroma, texture and overall quality. All the samples were presented and rated

simultaneously. A nine-point hedonic scale was used for the scoring with 1 being the worst, 9 the best, and 5 as neutral. For the military ration system a rating of 5 or greater is generally considered to be acceptable.

Statistical Design and Analysis

Various techniques as described by the U.S. Army Management Course (Anon., 1991a and 1991b) were used for the analyses. Analysis of variance was used to determine the significance of various factors that might have influenced the data. Depending on the study either a one, two or three way factor analysis was used. If any factor was shown to be significant, the least significant difference (lsd) was determined. To compare all the scores the method of Tukey was used (Anon., 1991a). To compare the scores of a single control the method of Dunnet was used (Anon., 1991a). Where appropriate, as described with the separate studies, a correlation coefficient and regression line was calculated.

STUDIES

A. Drying Rate and Quality of Peas

Procedure

The parameters investigated for this study were the mass load within the drying chamber (3.0, 4.0 and 5.0 kg) and microwave power levels (0.00, 0.25, 0.50 and 0.75 kW) for a total of 12 processing conditions. The bottom two drying trays were used here. These trays were split into equal left and right sections. The initial moisture of the peas was approximately 74%. A run was terminated when there was no mass change for three consecutive five-minute intervals.

The moisture of the dried peas was determined for both sides of each tray. The dried peas were then placed in cans, sealed under vacuum and held in storage at 0 ^{o}F until further analysis.

Results and Discussion

Drying Time

Drying curves of calculated moisture content as a function of drying time are shown in Figures 2a, b, c. These data from which the curves were drawn are also shown in the Appendix. The time to reduce the moisture content to 35% (i.e., removal of 81% of the initial moisture) is shown in Table 1. These data were also recalculated to show the time per kg of load mass. The use of MW power to augment CD reduced the drying time by a very significant amount at all drying conditions. The time of drying did increase with increased load mass. The time per unit mass was relatively constant over the range of masses at the same power level. Thus increasing the load would not appreciably change the drying time. The time per unit mass does decrease with the power level, particularly between 0.25 and 0.50 kW. There is a lesser decrease above 0.50 kW. Also, at a power level above 0.50 kW corona discharge begins to become significant, particularly at higher load levels. Therefore, there would be no advantage at a power level greater than 0.50 kW. The

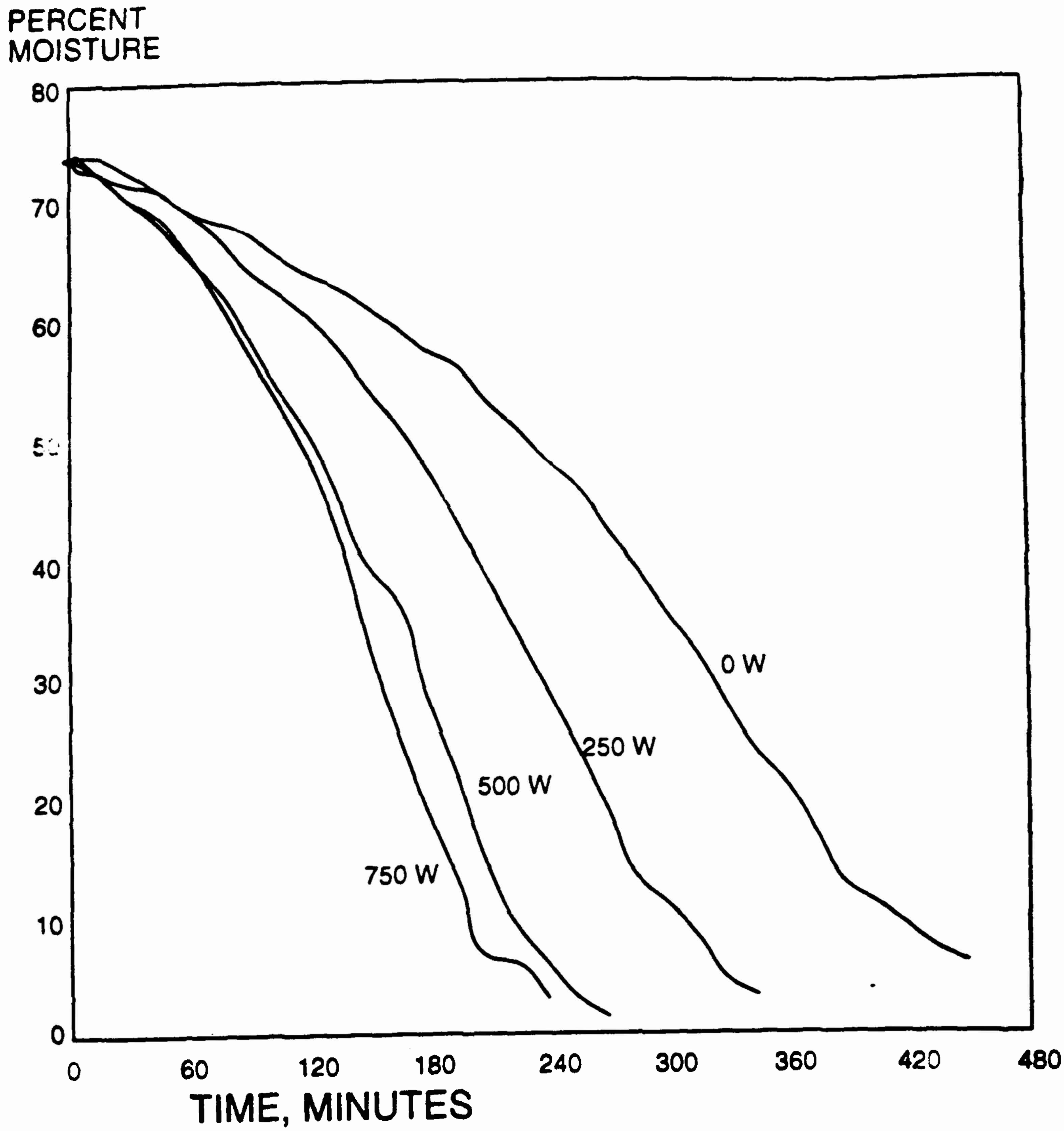

FIG. 2a - DRYING CURVES FOR PEAS, 3.0 kg LOAD MASS

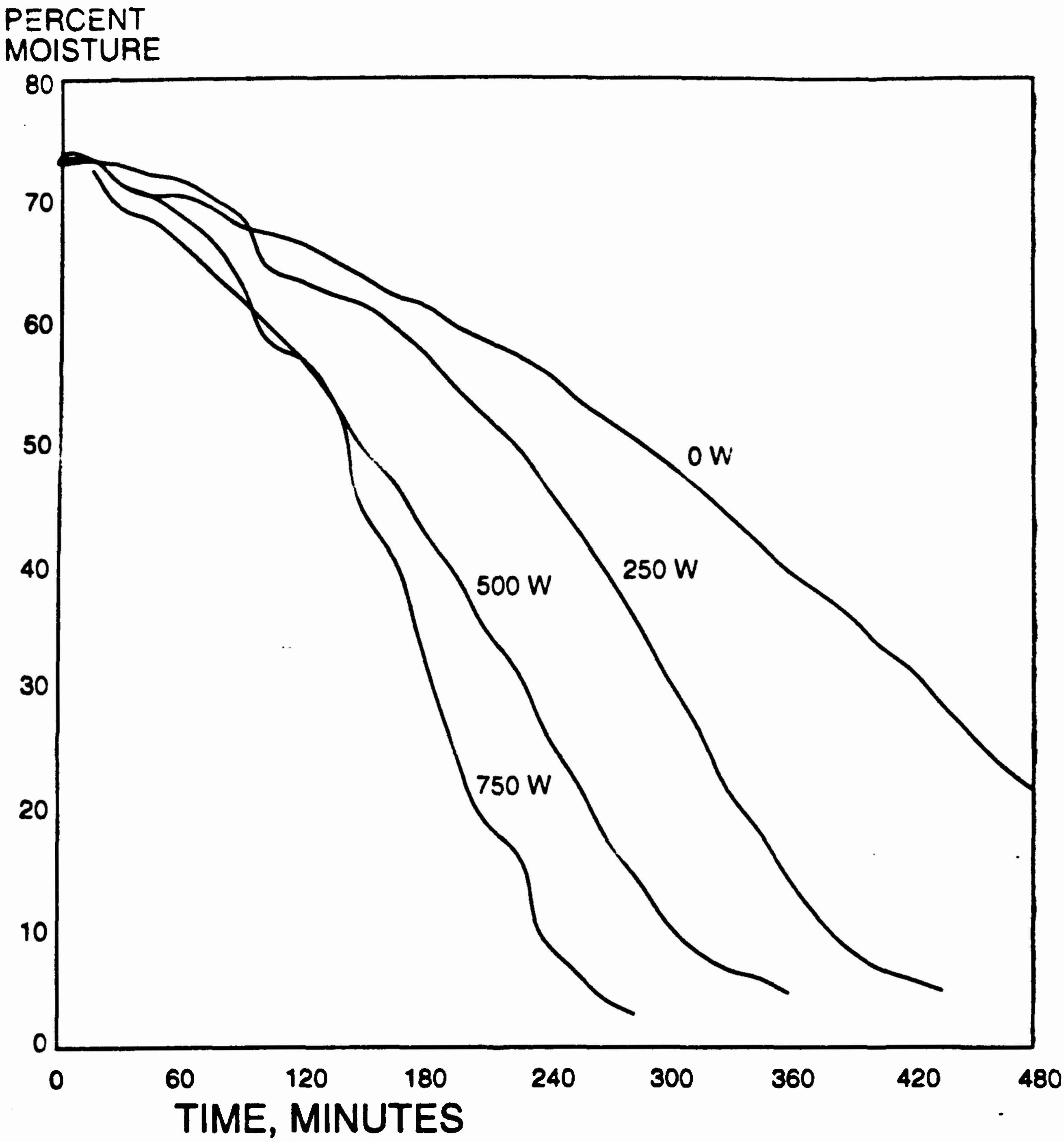

FIG. 2b - DRYING CURVES FOR PEAS, 4.0 kg LOAD MASS

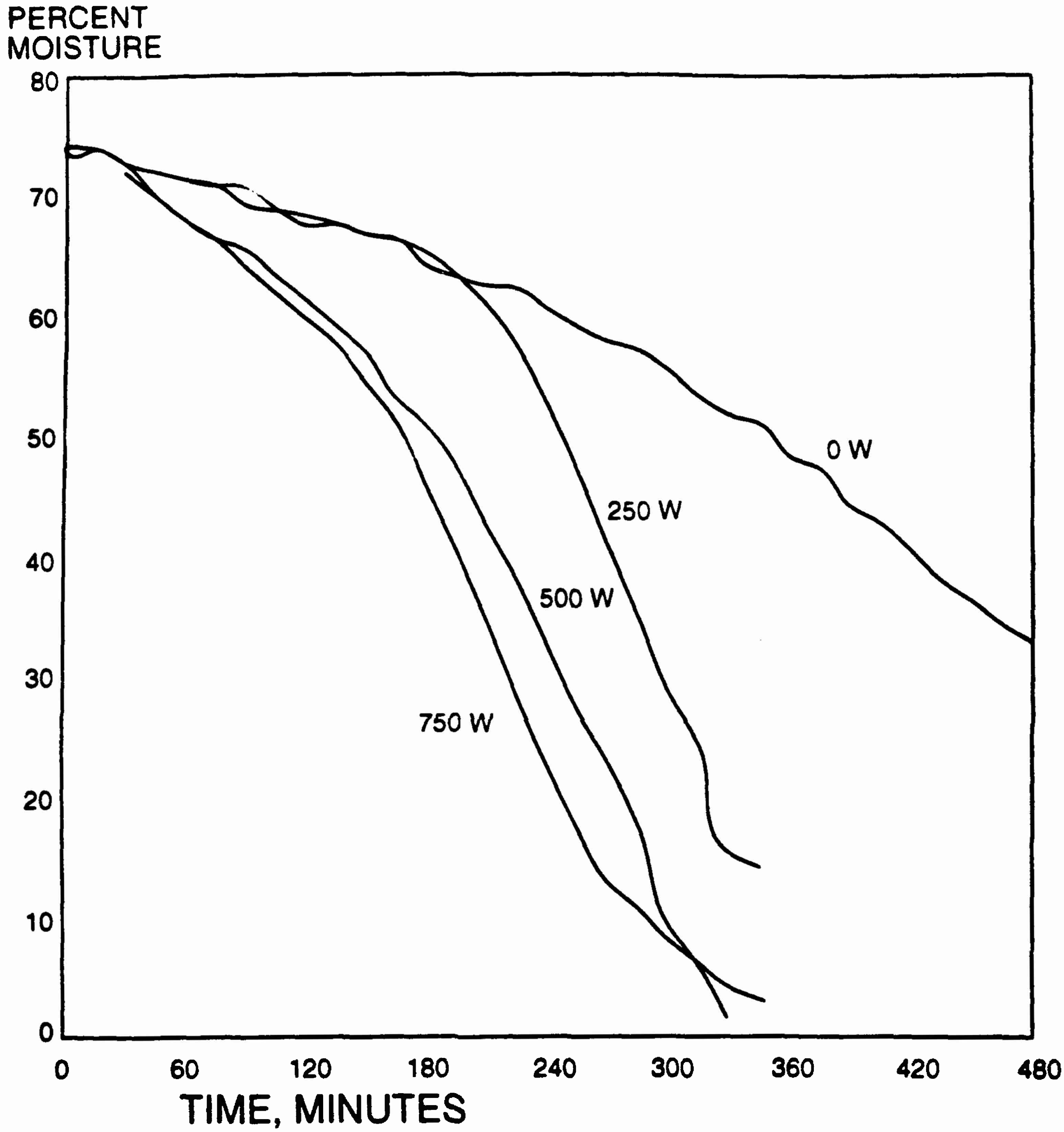

FIG. 2c - DRYING CURVES FOR PEAS, 5.0 kg LOAD MASS

power level should be matched to the load level for optimum operation.

If the only cost of power was the incremental cost, it would not be cost effective to go to a higher level than 0.25 kW. Doubling the power level does not decrease the drying time per unit mass by 50%. However, staying at the lower level would require larger equipment with increased costs associated with a larger drying chamber. Thus, it may be concluded that the optimum drying conditions would be 0.50 kW and as large a load size as possible (5.0 kg).

At the early stages (i.e. , reduction of moisture from 74 to 60%), the impact of the MW did not reveal significant differences, despite the mass difference. The original contact of the platen with the ice in the peas might dominate the rate of sublimation. As the ice layer shrinks towards the center of the particles as the result of the sublimation, the dry mass contacting the platen becomes a barrier for heat conduction and the heat radiation starts to pick up; this is when the MW shows its power. As expected, when the MW power increases so does the rate of moisture removal.

Rehydration Ratio

These data are shown in Table 2 and were analyzed with a three-way analysis of variance. The third factor was that of position on the trays within the chamber. There was a significant positive effect of the power level on these values. In addition all of the MW peas picked up more moisture than the CD peas. There was no effect of load mass or position. A rapid sublimation caused by the MW power might have made the internal structure of the MW peas more porous, thus allowing them to pick up more water during rehydration.

Shear Force

The rehydrated peas were used for the shear force analysis. The FTC™ Shear Press was used for these analyses. A single layer of peas, approximately 22 g, was placed in the 6.7 cm square cell. The 10 blade (0.32 cm thick blades) with the 1/3 range setting was used so the 100% mark on the scale was equivalent to 1,483 N force. Each reading was replicated four times. These averaged data are shown in Table 3. These data were analyzed with a three-way analysis of variance. The power level had a significant effect on these values. Also, a one-way analysis was used to compare all the processed samples to the control. All of the rehydrated peas, CD or MW, were harder than the undried, thawed control. The hardest peas were processed at 0.25 kW and the softest at 0.50 kW. There was no effect due to load mass or position although there was a slight trend of decreasing hardness with increased load.

Reflectance Color

The residue from the shear force studies was used for the reflectance color analysis. Both a three-way and one-way analysis of variance was used. These data are shown in Table 4 a, b, c. All three values of "L', "a" and "b" showed an effect of drying and rehydration on chlorophyll when compared to the control peas, as previously reported by Clydesdale and Francis (1976). They were all lighter, less

greenish, and either equal to, or slightly more yellowish, as depicted by greater "L' and negative "a" and "b" values.

For these treated samples, MW allows the samples to retain more green color, especially at lower power levels (e.g., 0.25 kW) than the CD process. The raw ingredients (i.e., Individual Quick Frozen (IQF) peas) used in this experiment might have been briefly blanched before freezing. Any residual peroxide enzyme, an enzyme responsible for wilting and discoloration, remaining in the sample might be inactivated by the MW energy that provides a "deep heating" to a material, without relying on a temperature gradient that occurs in the other blanching methods, such as water or steam. However, a higher energy level might have caused browning as shown by the loss of green color (decreasing negative "a" values) and an increase of the yellow color (decreasing "b" values). This discoloration is similar to the result on MW blanching of corn-on-the-cob as reported by Huxtoll et al. (1969) and Dietrich et al. (1990).

Sensory Panel

The sensory panel data are shown in Table 5. A two-way analysis of variance was used for evaluation as well as a one-way analysis to compare all the factors to the control. All of the characteristics have significantly lower scores than the control. The characteristics all scored in the range of 4.5 to 6.1. The control had scores that ranged from 7.2 to 8.2. Except for a power load effect on appearance and a load mass effect on flavor, the processing parameters had no significant effect on the scores. Power load had a negative effect on appearance. Load mass had a significant positive effect on flavor. In addition, the sensory quality seems to deteriorate as the MW power increases and improve as the mass load increases. In general, sensory quality seems to deteriorate as MW energy increases. The quality also improves as the mass load increases.

Correlation

In order to determine the correlation between the processing parameters and the subsequent product quality, correlation and regression analysis were done. This is shown in Table 6. There was an extremely high correlation coefficient for drying time as a function of load mass (+0.99) and as a function of power level (-0.97). In addition, the calculated drying time correlated well with the experimental values (+0.96) when the linear least squares method was used to calculate the data for both factors.

The shear force did not correlate well with the panel determination of the texture (+0.30). The method of instrumental analysis that was used may not have been the most appropriate to predict sensory properties. Panel appearance correlated moderately with reflectance "L" (-0.56) and "a" (-0.58), but not with "b" (+0.29).

B. Combination Drying of Peas and Green Beans

Procedure

In this study both frozen whole peas and sliced green beans were used.

Various combinations of CD and MW freeze-drying were used to determine the effect on drying rate if MW was used during only a portion of the drying process. Each run was done in two phase. The run conditions and the moisture removal rate are shown in Table 7. During Phase 1 the moisture content was reduced to approximately 65% of the original amount. during Phase 2 the moisture content was further reduced to a range of 20 to 35%.

For each run 2.4 kg of vegetables was placed evenly on a single plastic tray. The tray was placed on the bottom platen. The change in mass of vegetables on the tray was used to calculate the percent moisture as a function of time. The initial moisture was approximately 74% for the peas and 92% for the green beans.

Results and Discussion

Drying Time

The use of MW increased the drying rate; however, the impact varies with the duration that the MW power was applied as shown in Table 8. For both peas and green beans, application of MW at Phase 1 (removal of 65% of the initial moisture) and the CD at Phase 2 (achievement of 35% final moisture) has significantly increased the drying rate as compared to reversal of the process. In fact, the greatest reduction of the drying time occurred in Phase 1 where two-thirds of the water was removed. MW treatment not only increased the drying rate in Phase 1, it also helped in Phase 2 where CD was used (e.g., runs b and d, compared to run a). The faster sublimation might have rendered products more porous, thus permitting easier removal of the moisture vapor. The application of 0.25 kW of MW power in Phase 2 following MW treatment in Phase 1 seems to have a limited benefit to the peas (e.g., run b compared to run f). A more significant effect of MW on the drying of the green beans was observed at 0.50 kW, especially when used in both phases. The more pronounced effect of MW on peas than green beans might be attributed to the sample shape where the spherical form of the peas allows for more efficient and uniform drying than the cylindrical form of the green beans.

Rehydration Ratio

The rehydration ratio data are shown in Table 8. There were no differences observed for the peas. The green bean samples dried only by CD had a greater value than any of the others. The shape of the sample determines the efficiency of rehydration due to physical damage of the bean tissue. The damage might also have occurred because of interaction with the MW field.

Shear Force

Both the SMS-TAXT2™ Texturometer and the original FTC™ shear press were used for the shear force measurements. As the two instruments had a correlation coefficient of +0.807 for the peas and +0.712 for the green beans only the data from the Texturometer are reported in Table 9. The single blade cell was used. The blade was 0.3 cm in thickness and 6.5 cm in length. A blade speed of 0.5 mm per second was used for the peas and 2.0 mm per second for the green beans. Seven individual intact vegetables were positioned to completely cover the slit. Each measurement

was replicated four times. The peak value is the data reported in Table 9. For both vegetables, the CD products were more resistant to penetration than all the MW products and were comparable to the undried frozen control. MW appears to have a softening effect especially when applied at Phase 2 on the green beans.

Reflectance Color

The reflectance color data are shown in Table 10 a, b, c. There were no significant color differences for the green beans although the frozen control did have a nonsignificant lower "L" value. The CD peas had a greater "L" value, greater negative "a" value and a greater "b" value than the frozen control and the MW dried products.

C. Ground Beef

Procedure

Proteinaceous foods are more heterogeneous than vegetables. Further the fat content makes the food mass a complex polymeric system. The effect of microwaves on this system needs to be thoroughly studied to determine the optimal processing conditions.

Whole, unfrozen beef rounds, tops and bottom were used. The meat was trimmed of fat the same day that it was received. The trimmed meat and the fat were stored separately at 4 ^{o}C overnight. The next day the lean portion, approximately 7% ft, and the fat portion, approximately 65% fat, were coarse ground separately. These lean and fat grinds were then mixed to the approximate final fat content. This gave products of different fat contents and grind sizes so that the effect of these parameters on the drying process could be determined.

The mixes were then individually reground through 0.5, 0.8 and 1.3 cm grinder heads. Samples from the final grinds were then analyzed for percent fat and moisture. The data are shown in Table 11a. The meat was then divided into approximately 2.0 kg batches and then frozen at -29 ^{o}C until used.

Three fat percentages and three grind sizes were used. Each portion was dried with both CD and MW. All the runs were done at 0.50 kW.

Each batch of ground beef was thawed at room temperature so that the entire amount could be placed evenly on the plastic drying tray. The meat covered the right front quarter of the tray, an area of 27 x 27 cm, to a depth of 2.5 cm. The meat on the tray was frozen and drying was initiated. Only the bottom platen was used.

The run was terminated when approximately 90% of the initial moisture had been removed as calculated from the mass loss. Drying curves for moisture removal at different levels of grind size, fat content and drying method are shown in Table 12 a, b, c.

Results and Discussion

Drying Time

The data analysis is shown in Table 13 a, b, c. With all three methods of

calculating the drying rate, MW drying was significantly faster than CD drying. There were no differences due to fat content or grind size except with rate c where increased fat content decreased the drying time.

The analysis of only the CD data showed the effect of fat content on the drying time with all three curves. Increased fat content decreased the drying time. There was an effect of grind size only on curve a, where increased grind size increased the drying time.

The analysis of only the MW data showed no effect of fat content and an effect of grind size on curve b only, where the middle grind size had the greatest drying time.

Rehydration Ratio

The rehydration ratio data is shown in Table 14. When all the data were analyzed together there were significant effects shown with all three processing factors. There were differences among the individual data points. Most significant was the process effect where CD drying picked up more water than did the MW drying. The water pickup decreased with increasing fat content and also with increased grind size. The same results were shown when the CD and MW data were analyzed separately.

This data analysis is somewhat misleading as the meat was essentially cooked during the rehydration process and the fat rendered out. This result is shown in Table 11b where the protein to fat ratio has increased on rehydration, indicating that fat has been removed. That is also why some of the values are negative.

Reflectance Color

Reflectance color data are shown in Table 14 a, b, c. There were significant differences with "L" for both the dried and rehydrated samples. None of this data showed an effect due to the drying process. The "L" values were significantly different for both fat content and grind size for both the dehydrated and rehydrated samples. Both sets of values showed a positive effect that increased with the fat content. There was no correlation with the grind size.

The "a" values showed no significance except for the effect of fat with the rehydrated samples. However, the effect of fat content was not significant.

The "b" values showed a significant effect for both fat content and grind size on both the dehydrated and rehydrated samples. Fat content had a positive effect and grind size a negative effect for the rehydrated samples but were not correlated for the dehydrated samples.

Both the CD and MW data were separately analyzed. With CD data the fat content was significant for "L", "a" and "b" values. Grind size was significant for "a" and "b" only. These values did not show correlation. For CD rehydrated samples, "L" and "b" values showed significance. Fat content had a positive effect and grind size a negative effect on these values. For MW data, the only significance shown with the dehydrated samples was grind size on "L" values. However, the results did not show correlation. With the rehydrated samples, the fat content affected all three values. The "L" values had a positive correlation with the fat content. The other

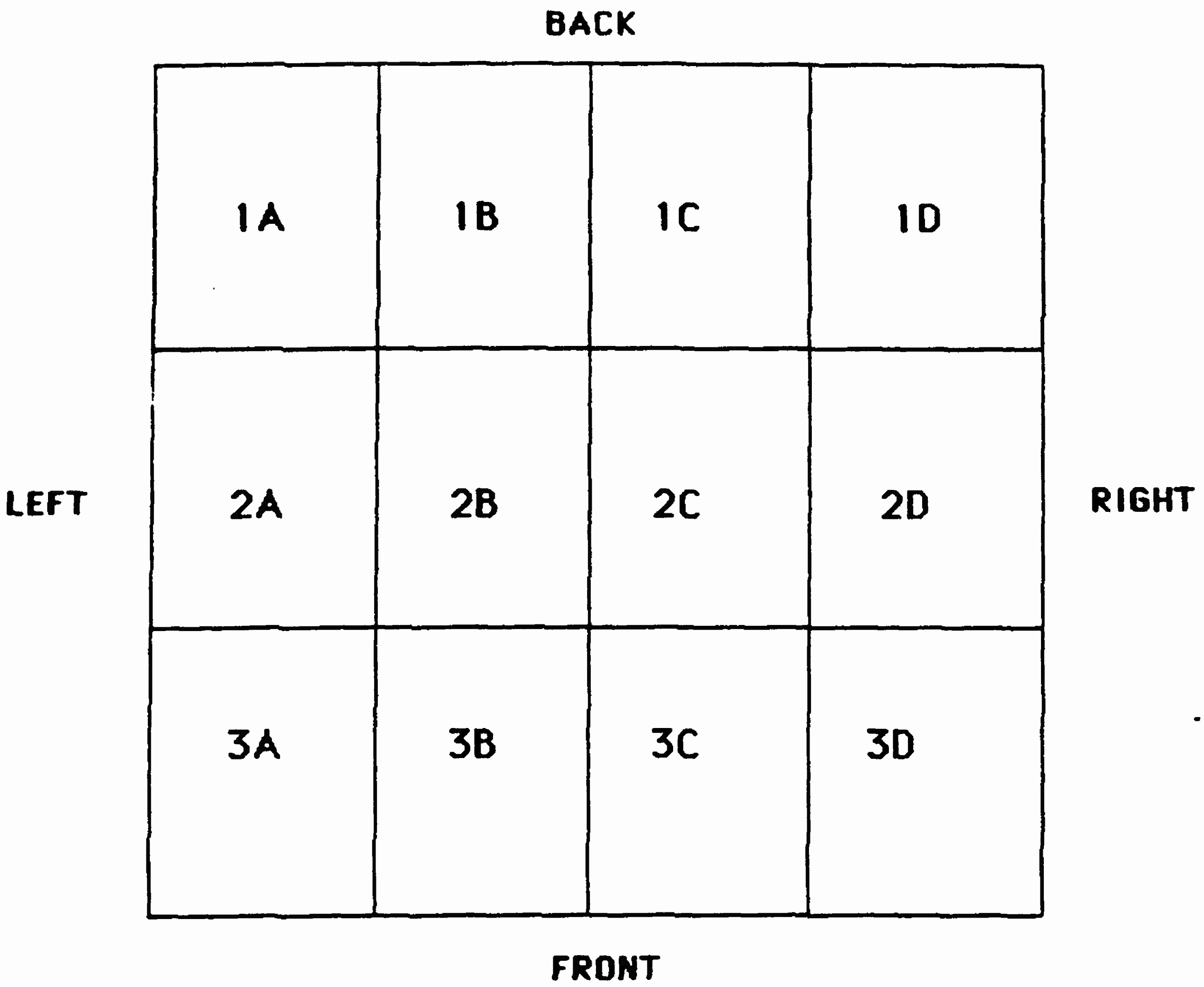

FIG. 3 - ARRANGEMENT OF COMPARTMENTS IN DRYING TRAY

values were not correlated.

As with the data on rehydration ratio, the values for the rehydrated samples are somewhat misleading. The rehydration process essentially cooked the meat so that it all turned brown.

Proximate Analysis Ratios

These values are included with Table 11 b. They are included to illustrate what is occurring during processing. The ratio of moisture to protein in the initial, untreated samples was fairly constant, i.e., 3.09 to 3.28. This is to be expected as the moisture is associated with the protein, not the fat. The ratio decreased considerably in the dehydrated samples because of the moisture removal. The ratio increased in the rehydrated product and again was fairly constant, i.e., 1.51 to 2.17. The ratio did not increase back to the initial values, indicating that the meat was not completely rehydrated.

The ratio of moisture to fat in the initial samples was also as expected. Since moisture is associated with protein, this factor decreased as the fat portion increased. The ratio decreased to very low values on dehydration because of the moisture removal. It increased considerably with rehydration, not only because of the moisture addition, but the ratio was also affected by the rendering out of the fat.

The ratio of protein to fat in the initial samples was as expected. The protein decreased as the fat increased. The ratio held fairly constant with the dehydrated samples indicating that mostly moisture was removed. However, these ratios all increased with the rehydrated products, thus demonstrating the rendering out of the fat.

D. Uniformity of Drying

Procedure

The drying rate analysis was done with investigation B of these studies. In that study a compartmented tray was used for drying. The 53.3 x 50.8 cm tray was divided into 12 equally sized compartments, each 4.4 x 4.2 cm. This array is shown in Figure 3.

After each phase of the dying cycle the mass of vegetables in each compartment was measured. After Phase 1 the vegetables were returned to the proper compartment and drying completed in Phase 2.

For purposes of analysis the data were first transformed to a percentage of the original mass and transformed again as the variation from the mean value for each run. The data were combined as shown in Table 15. The data and analyses are shown in Tables 16 and 17. Analysis of variance was used to analyze the data.

Results and Discussion

The moisture removal (drying rate) was not uniform within the drying chamber. This nonuniformity is significant with the MW drying, but not with the CD drying.

Positions 1A and 3A appear to have the least moisture loss (less dry). Position

1C the most loss (most dry). When the data were combined, there was a row effect with MW and also with CD, but with no column effect. There was an overall position effect with MW but not with CD.

The variation in drying rate with MW confirms what has been previously reported (Datta and Hu, 1992). The pattern that was shown in our chamber will not be necessarily true in other chambers, each of which should be studied separately.

CONCLUSIONS

These studies have demonstrated that MW freeze-drying greatly increases the drying rate when compared to CD freeze-drying. In general there is no loss in quality.

Meat with a large fat content can be successfully dried as well as products with a large carbohydrate content (vegetables).

Drying does not occur uniformly within the MW drying chamber. In order to achieve uniform moisture removal, a mechanical modification within the chamber is needed. Future studies might explore the use of a rotating fan, turntable or infrared controlled MW guide.

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TABLE 1. Time to Reduce Moisture of Peas to 35% (81% Removed) (Study A)

POWER (kW)	MASS (kg)	TIME (min)	TIME (min/kg)	N
0	3.0	300	100	1
0	4.0	391	98	1
0	5.0	464	93	1
0.25	3.0	220	73	1
0.25	4.0	285	71	1
0.25	5.0	362	72	1
0.50	3.0	152	51	1
0.50	4.0	201	50	1
0.50	5.0	233	47	1
0.75	3.0	143	48	1
0.75	4.0	175	44	1
0.75	5.0	208	42	1

Factor	F	Significance	Least Significant Difference 99%	Least Significant Difference 95%
Power	47.8	99%	89.5	57.2
Mass	22.0	99%	122.2	53.4

Summary of Time	Average (min.)
1. Power (kw)	
Σ0	385
Σ0.25	289
Σ0.50	195
Σ 0.75	175
2. Load Mass (kg)	
Σ 3.0	204
Σ 4.0	263
Σ 5 .0	317

TABLE 2. Rehydration Ratio of Partially Dried Peas (Study A)

POWER (KW)	MASS (kg)	REHYD. RATIO	N	SD	RATIO BY POSITION ON TRAY A	B	C	D
0	3.0	1.93	4	0.28	1.57	2.18	2.12	1.84
0	4.0	1.98	4	0.12	1.94	2.11	1.84	2.04
0	5.0	1.85	4	0.15	1.87	2.04	1.75	1.72
0.25	3.0	2.03	4	0.25	2.03	2.16	1.68	2.25
0.25	4.0	2.13	4	0.23	2.33	2.29	1.85	2.03
0.25	5.0	2.08	4	0.07	2.03	2.16	2.04	1.86
0.50	3.0	2.27	4	0.26	1.96	2.46	2.51	2.14
0.50	4.0	2.24	4	0.11	2.25	2.30	2.08	2.34
0.50	5.0	2.27	4	0.05	2.25	2.34	2.28	2.21
0.75	3.0	2.19	4	0.01	2.24	2.28	2.17	2.07
0.75	4.0	2.39	4	0.06	2.31	2.44	2.42	2.40
0.75	5.0	2.44	4	0.20	2.57	2.29	2.66	2.25

Factor	F	Significance	Least Significant Difference 99%	95%
Power	15.7	99%	0.67	0.50
Mass	1.0	NSD	-	-
Position	2.3	NSZD	-	-

Summary of Values	Average (Ratio)
1. Power (kw)	
Σ 0	1.92
Σ 0.25	2.08
Σ 0.50	2.26
Σ 0.75	2.34
2. Mass (kg)	
Σ 3.0	2.11
Σ 4.0	2.19
Σ 5.0	2.16
3. Position	
Σ A	2.11
Σ B	2.25
Σ C	2.12
Σ D	2.10

TABLE 3. Shear Force (Newtons) of Rehydrated Peas (Study A)

POWER (kW)	MASS (kg)	FORCE (ave.)	N	SD	SHEAR FORCE BY POSITION ON TRAY A	B	C	D
0	3.0	692	16	79	715	715	645	693
0	4.0	615	16	85	660	619	552	630
0	5.0	613	16	97	612	586	615	637
0.25	3.0	693	16	80	719	733	664	656
0.25	4.0	665	16	102	630	763	593	675
0.25	5.0	677	16	83	653	653	689	682
0.50	3.0	599	16	55	604	600	593	597
0.50	4.0	626	16	70	653	593	637	623
0.50	5.0	549	16	156	653	626	552	556
0.75	3.0	613	16	61	589	597	623	645
0.75	4.0	600	16	80	597	615	641	545
0.75	5.0	637	16	89	589	660	645	653
Control		515	4	53				

Factor	F	Significance	Least Significant Difference 99%	95%
Power	8.6	99%	56.0	48.9
Mass	1.8	NSD	-	-
Position	0.75	NSD	-	-

Summary of Values	Average Shear Force
1. Power (kW)	
Σ 0	640
Σ 0.25	678
Σ 0.50	[illegible]
Σ 0.75	617
2. Mass (kg)	
Σ 3.0	649
Σ 4.0	627
Σ 5.0	619
3. Position	
Σ A	640
Σ B	650
Σ C	621
Σ C	633

TABLE 4. Reflectance Scores of Rehydrated Peas (Study A)

a. "L"

POWER (kW)	MASS (kg)	REFLEC. SCORE	N	SD	REFLEC. SCORE BY POSITION ON TRAY A	B	C	D
0	3.0	36.11	8	2.03	36.91	36.97	38.04	34.53
0	4.0	35.96	8	1.52	35.81	33.97	37.35	36.71
0	5.0	35.41	8	1.47	35.89	36.18	36.04	33.53
0.25	3.0	33.46	8	1.41	33.71	31.97	35.21	33.01
0.25	4.0	32.88	8	1.13	32.52	32.57	33.29	33.17
0.25	5.0	34.05	8	0.80	33.75	33.49	j34.46	33.50
0.50	3.0	35.01	8	1.01	34.85	35.59	33.88	35.76
0.50	4.0	33.24	8	1.28	32.69	33.49	33.27	33.54
0.50	5.0	33.34	8	1.53	31.40	33.81	33.61	34.55
0.75	3 0	34.62	8	1.41	35.63	35.68	34.37	32.84
0.75	4.0	33.42	8	0.93	34.24	32.76	33.68	33.00
0.75	5.0	34.30	8	1.11	33.15	34.59	34.83	34.37
Control		30.59	2	0.52				

Factor	F	Significance	Least Significant Difference 99%	95%
Power	14.3	99%	1.25	1.02
Mass	3.8	95%	–	0.71
Position	1.4	NSD	–	–
Comparison to Control	6.4	99%	3.77	3.02

Summary of Values	Ave. Refl. Score
1. Power (kW)	
Σ 0	35.82
Σ 0.25	33.46
Σ 0.50	33.86
Σ 0.75	34.11
2. Mass (kg)	
Σ 3.0	34.80
Σ 4.0	33.88
Σ 5.0	34.26
3. Position	
Σ A	34.22
Σ B	34.26
Σ C	34.84
Σ D	34.04

TABLE 4. Reflectance Scores of Rehydrated Peas (Study A) (Continued)

b. "a" (all values are negative)

POWER (kW	MASS (kg)	REFL SCORE	N	SD	REFL. SCORE BY POSITION ON TRAY A	B	C	D
0	3.0	4.59	8	2.17	2.22	7.42	3.31	5.41
0	4.0	7.44	8	0.39	7.76	7.25	7.44	7.32
0	5.0	7.09	8	0.51	7.33	6.70	7.40	6.94
0.25	3.0	8.44	8	0.41	8.16	8.35	9.05	8.20
0.25	4.0	8.17	8	0.55	7.74	7.83	8.79	8.31
0.25	5.0	8.03	8	0.60	7.17	8.05	8.58	8.34
0.50	3.0	6.41	8	0.37	6.69	6.50	6.24	6.23
0.50	4.0	7.22	8	0 88	5.35	7.61	8.18	6.25
0.50	5.0	6.65	8	0.25	6.38	6.76	6.67	6.81
0.75	3.0	3.89	8	2.05	1.25	3.03	6.13	5.14
0.75	4.0	4.27	8	1.52	2.09	4.90	4.40	5.71
0.75	5.0	6.32	8	0.69	6.48	5.38	5.53	6.91
Control		8.80	2	0.35				

Factor	F	Significance	Least Significant Difference 99%	95%
Power	32.3	99%	1.11	0.91
Mass	8.8	99%	0.90	0.72
Position	3.8	95%	-	0.91
Comparison to Control	2.1	95%	-	3.94

Summary of Values	Ave. Refl. Score
1. Power (kW)	
Σ 0	6.37
Σ 0.25	8.21
Σ 0.50	6.76
Σ 0.75	4.83
2. Mass (kg)	
Σ 3.0	5.83
Σ 4.0	6.78
Σ 5.0	7.23
3. Position	
Σ A	5.72
Σ B	6.64
Σ C	6.81
Σ D	6.80

TABLE 4. Reflectance Scores of Rehydrated Peas (Study A) (Continued)

c. "b"

POWER (kW)	MASS (kg)	REFL. SCORE	N	SD	REFL. SCORE BY POSITION ON TRAY A	B	C	D
0	3.0	15.04	8	1.02	13.71	16.20	14.91	15.35
0	4.0	16.12	8	0.62	15.89	15.46	16.71	16.42
0	5.0	15.68	8	1.08	16.11	16.37	16.17	14.07
0.25	3.0	15.12	8	0.67	15.32	14.56	15.80	14.73
0.25	4.0	15.41	8	0.56	15.11	15.34	15.80	15.40
0.25	5.0	14.48	8	0.51	15.90	16.21	16.03	15.59
0.50	3.0	14.76	8	0.52	14.54	15.12	14.46	14.92
0.50	4.0	14.81	8	0.88	14.17	15.02	15.46	14.60
0.50	5.0	14.48	8	0.64	13.66	14.97	14.77	14.52
0.75	3.0	14.66	8	0.59	14.28	15.06	14.97	14.34
0.75	4.0	14.51	8	0.40	14.46	14.95	13.97	14.66
0.75	5.0	14.69	8	0.79	13.80	14.62	14.79	15.57
Control		14.69	2	0.57				

Factor	F	Significance	Least Significant Difference 99%	95%
Power	13.0	99%	0.66	0.54
Mass	2.0	NSD	–	–
Position	3.7	95%	-	0.54
Comparison to Control	4.5	99%	2.06	1.67

Summary of Values	Ave. Refl. Score
1. Power (kW)	
Σ 0	15.61
Σ 0.25	15.38
Σ 0.50	14.68
Σ 0.75	14.62
2. Mass (kg)	
Σ 3.0	14.90
Σ 4.0	15.22
Σ 5.0	15.20
3. Position	
Σ A	14.75
Σ B	15.32
Σ C	15.32
Σ D	15.01

TABLE 5 Sensory Rating* of Rehydrated Peas (Study A)

*All values are average of 12 testers' ratings on 9-point hedonic scale

a. Appearance

POWER (kW)	MASS (kg)	RATING	N	SD
0	3.0	5.63	12	1.46
0	4.0	5.29	12	1.51
0	5.0	5.58	12	1.31
0.25	3.0	5.42	12	1.78
0.25	4.0	5.71	12	1.45
0.25	5.0	4 83	12	1.47
0.50	3.0	4 42	12	1.31
0.50	4.0	5.25	12	1.36
0.50	5.0	5.25	12	1.48
0.75	3.0	4.58	12	1.51
0.75	4.0	4.00	12	1.54
0.75	5.0	5.17	12	1.11
Control		8.20	12	1.03

Factor	F	Significance	Least Significant Difference 99%	95%
Power	3.54	95%	-	2.81
Mass	0.31	NSD	-	-
Comparison to Control	18.2	99%	2.21	1.85

Summary of Values	Ave. Rating
1. Power (kW)	
Σ 0	5.50
Σ 0.25	5.32
Σ 0.50	4.97
Σ 0.75	4.92
2. Mass (kg)	
Σ 3.0	5.01
Σ 4.0	5.06
Σ 5.0	5.21

TABLE 5. **Sensory Rating of Rehydrated Peas (Study A) (Continued)**

b. Flavor

POWER (KW)	MASS (kg)	RATING	N	SD
0	3.0	5.67	12	1.23
0	4.0	5.50	12	1.32
0	5.0	5.58	12	1.24
0.25	3.0	5.50	12	1.73
0.25	4.0	6.04	12	1.54
0.25	5.0	5.58	12	1.51
0.50	3.0	5.00	12	1.60
0.50	4.0	5.75	12	1.36
0.50	5.0	5.67	12	1.61
0.75	3.0	4.92	12	1.78
0.75	4.0	5.08	12	1.56
0.75	5.0	6.08	12	1.56
Control		7.17	12	0.83

Factor	F	Significance	Least Significant Difference 99%	95%
Power	1.85	NSD	–	–
Mass	6.14	99%	1.80	1.38
Comparison to Control	9.96	99%	1.73	1.45

Summary of Values	Ave. Rating
1. Power (kW)	
$\sum 0$	5.58
$\sum 0.25$	5.71
$\sum 0.50$	5.47
$\sum 0.75$	5.36
2. Mass (kg)	
$\sum 3.0$	5.27
$\sum 4.0$	5.59
$\sum 5.0$	5.73

TABLE 5. Sensory Rating of Rehydrated Peas (Study A) (Continued)

c. Aroma

POWER (kW)	MASS (kg)	RATING	N	SD
0	3.0	5.92	12	1.51
0	4.0	5.75	12	1.36
0	5.0	6.00	12	1.41
0.25	3.0	6.08	12	1.31
0.25	4.0	6.25	12	1.06
0.25	5.0	6.00	12	1.28
0.50	3.0	5.50	12	1.38
0.50	4.0	5.83	12	1.47
0.50	5.0	6.00	12	1.13
0.75	3.0	5.42	12	1.68
0.75	4.0	5.50	12	1.17
0.75	5.0	6.33	12	1.15
Control		7.33	12	0.98

Factor	F	Significance	Least Significant Difference 99%	95%
Power	0.74	NSD	-	-
Mass	1.22	NSD	-	
Comparison to Control	3.41	99%	2.52	2.11

Summary of Values	Ave. Rating
1. Power (kW)	
Σ 0	5.89
Σ 0.25	6.11
Σ 0.50	5.78
Σ 0.75	5.75
2. Mass (kg)	
Σ 3.0	5.73
Σ 4.0	5.83
Σ 5.0	6.08

TABLE 5. Sensory Rating of Rehydrated Peas (Study A) (Continued)

d. Texture

POWER (kW)	MASS (kg)	RATING	N	SD
0	3.0	5.58	12	1.16
0	4.0	5.58	12	1.16
0	5.0	5.33	12	1.23
0.25	3.0	5.83	12	1.27
0.25	4.0	5.83	12	1.40
0.25	5.0	5.17	12	1.40
0.50	3.0	5.08	12	1.24
0.50	4.0	5.58	12	1.31
0.50	5.0	5.25	12	1.91
0.75	3.0	4.75	12	1.66
0.75	4.0	5.00	12	1.28
0.75	5.0	5.75	12	1.42
Control		7.50	12	1.00

Factor	F	Significance	Least Significant Difference 99%	95%
Power	0.91	NSD	-	-
Mass	0.28	NSd	-	-
Comparison to Control	3.66	99%	3.34	2.80

Summary of Values	Ave. Rating
1. Power (kw)	
Σ 0	5.50
Σ 0.25	5.61
Σ 0.50	5.30
Σ 0.75	5.17
2. Mass (kg)	
Σ 3.0	5.31
Σ 4.0	5.50
Σ 5.0	5.38

TABLE 5. Sensory Rating of Rehydrated Peas (Study A) (Continued)

e. Overall Quality

POWER (kW)	MASS (kg)	RATING	N	SD
0	3.0	5.50	12	1.00
0	4.0	5.50	12	0.90
0	5.0	5.75	12	0.87
0.25	3.0	5.67	12	1.37
0.25	4.0	5.54	12	1.70
0.25	5.0	5.25	12	1.22
0.50	3.0	5.00	12	0.95
0.50	4.0	5.58	12	1 .08
0.50	5.0	5.17	12	1.41
0.75	3.0	4.63	12	1.52
0.75	4.0	4.63	12	0.93
0.75	5.0	5.58	12	1.38
Control		7.58	12	0.90

Factor	F	Significance	Least Significant Difference 99%	95%
Power	1.84	NSD	-	-
Mass	0.44	NSD	-	-
Comparison to Control	7.19	99%	2.58	2.16

Summary of Values	Ave. Rating
1. Power (kW)	
Σ 0	5.58
Σ 0.25	5.49
Σ 0.50	5.25
Σ 0.75	4.95
2. Mass (kg)	
Σ 3.0	5.20
Σ 4.0	5.31
Σ 5.0	5.44

TABLE 6. Correlation and Regression for Peas (Study A)

		Correlation	Linear Least Squares		
		(r)	Slope	Intercept (kW)	Intercept (kg)
1. Drying Time = f (Mass)	0 kW	+0.998	57.0	92.0	
	0.25 kW	+0.999	5.0	71.0	
	0.50 kW	+0.93	33.3	40.5	
	0.75 kW	+0.999+	45.3	32.5	
2. Drying Time = f (Power)	3.0 kg	-0.956	257.8		-214.8
	4.0 kg	-0.970	372.8		-292.8
	5.0 kg	-0.972	451.3		-358.8
3. Drying Time = f (Power, Mass)		+0.948	62.5	75.0	270.0
4. Shear Force x Sensory Panel Texture		+0.298			
5. Sensory Panel Appearance x "L"		-0.559			
Sensory Panel Appearance x "a"		-0.580			
Sensory Panel Appearance x "b"		+0.291			
6. Percent Final Moisture x Rehydration Ratio		-0.490			

TABLE 7. Drying Conditions and Drying Rates for Peas and Green Beans (Study B)

			Time of Drying (minutes)+							
	MW Power (Watts)		Peas				Green Berans			
	Run	for Phase	Phase		Savings#		Phase		Savings#	
1* 2**	1*		2**	1*	2**	1*	2**	1*	2**	
a	0	0	285	475	-	-	285	595	-	-
b	250	0	170	375	115	-	240	570	45	-
c	0	250	255	405	-	70	310	555	-	40
d	500	0	120	300	165	-	225	485	60	-
e	0	500	245	350	-	125	325	450	-	145
f	250	250	180	355	105	120	245	270	40	325
g	500	500	135	235	150	240	240	295	45	300

+ All times are rounded to the nearest 5 minutes
# As compared to CD drying (Run a)

* Removal of 65% of initial moisture
** Achievement of 35% final moisture after removal of 65% of initial

TABLE 8. Rehydration Ratio for Peas and Green Beans in Two-Step Drying Process (Study B)

Run	Rehydration Ratio		Average	Final Percent Moisture
Peas				
a	1.57	1.38	1.48	30.8
b	1.56	1.62	1.59	39.4
c	1.78	1.76	1.77	28.3
d	1.60	1.59	1.60	37.7
e	1.85	1.93	1.89	18.7
f	1.81	1.96	1.89	24.6
g	1.54	1.65	1.60	35.1
	F = 2.83, NSD			
Green Beans				
a	7.68	6.98	7.33	27.4
b	[illegible]	6.12	6.27	34.5
c	5.72	5.77	5.75	32.1
d	4.74	4.90	4.82	37.0
e	5.05	4.55	4.85	25.0
f	6.21	6.50	6.36	26.6
g	5.04	4.79	4.91	35.2
	F = 31.0, 99% significance			
	LSD (99%) = 1.38; (95%) = 1.01			

TABLE 9. Texture Values (Shear Force Measurements) for Peas and Green Beans for Two-Step Drying Process (Study B)

RUN	VALUES (NEWTONS)				AVERAGE	
A Peas						
a	54.9	61.9	62.1	60.0	60.8	
b	51.0	54.4	56.2	46.0	51.9	
c	51.5	54.7	52.8	48.5	51.9	
d	45.7	46.0	50.0	42.8	46.1	
e	51.1	47.1	45.4	49.2	48.2	
f	57.9	55.9	52.1	50.5	54.1	
g	51.2	52.5	49.9	46.9	50.1	
h	62.0	68.6	63.7	57.2	62.9	(frozen control)
	F = 13.2, 99% significance					
	LSD (99%) = 9.2; (95%) = 7.6					
B. Green Beans						
a	131.9	136.2	135.7	130.1	133.5	
b	109.2	104.4	101.3	89.2	101.0	
c	97.6	95.9	73.0	78.9	86.3	
d	98.8	98.1	108.1	107.4	103.0	
e	73.8	94.8	63.5	91.2	85.8	
f	113.9	120.9	124.0	104.8	122.2	
g	105.2	96.1	120.0	141.3	115.9	
h	134.1	123.5	142.8	137.2	134.4	(frozen control)
	F = 14.2, 99% significance					
	LSD (99%) = 29.1; (95%) = 24.0					

TABLE 10. **Reflectance Color of Peas and Green Beans for Two-Step Drying Process (Study B)**

a. "L" Values

RUN	VALUES				AVERAGE	
A. Peas						
a	33.84	33.30	34.14	34.90	34.05	
b	29.67	32.91	31.46	32.72	31.69	
c	32.76	27.84	31.86	30.95	30.85	
d	29.73	32.90	32.29	32.84	31.94	
e	31.51	32.49	31.18	34.16	32.34	
f	32.50	31.84	30.65	32.66	31.91	
g	30.45	30.71	32.42	32.73	31.58	
h	30.55	31.12	3028	30.03	30.50	(frozen control)
	F = 3.05, 95% significance					
	LSD (95%) = 3.06					
B. Green Beans						
a	33.06	31.56	27.40	31.11	30.78	
b	34.20	34.30	29.10	29.83	31.86	
c	33.35	28.61	27.91	30.59	30.12	
d	29.03	37.01	27.81	31.73	31.40	
e	30.17	30.25	31.05	29.86	30.33	
f	31.04	29.63	29.81	30.77	30.31	
g	32.25	29.78	30.34	28.22	30.15	
h	26.04	27.71	26.19	30.37	27.58	(frozen control)
	F = 1.20, NSD					

TABLE 10. Reflectance Color of Peas and Green Beans for Two-Step Drying Process (Study B)

b. "a" Values

(all values are negative)

RUN	VALUES				AVERAGE	
A. Peas						
a	8.71	8.45	8.20	8.38	8.44	
b	7.12	7.85	6.78	8.14	7.47	
c	7.31	7.15	8.21	7.17	7.46	
d	7.57	7.10	6.96	8.10	7.43	
e	8.45	6.90	7.50	7.33	7.55	
f	8.38	6.94	7.83	7.55	7.68	
g	7.55	6.85	7.16	6.53	7.02	
h	7.12	7.49	7.00	7.25	7.22	(frozen control)
	F = 2.80 (95% significance)					
	LSD (95%) = 1.17					
B. Green Beans						
a	3.32	2.40	3.54	2.41	2.92	
b	4.49	2.40	2.96	3.22	3.27	
c	3.89	3.40	3.93	3.23	2.61	
d	3.15	3.73	1.96	3.49	3.08	
e	3.47	2.89	3.32	3.96	3.41	
f	3.17	3.68	3.24	3.86	3.49	
g	3.20	1.21	2.15	3.22	2.45	
h	3.66	2.11	2.38	2.93	2.77	(frozen control)
	F = 1.38 (NSD)					

TABLE 10. Reflectance Color of Peas and Green Beans for Two-Step Drying Process (Study B)

c. "b" Values

RUN	VALUES				AVERAGE	
A. Peas						
a	16.09	15.07	15.70	16.09	15.74	
b	13.69	14.88	14.39	15.03	14.50	
c	14.80	12.89	14.98	14.15	14.21	
d	13.81	15.23	15.25	15.59	14.97	
e	14.71	14.72	14.81	14.86	14.78	
f	15.16	14.48	14.50	14.37	14.62	
g	13.77	13.39	14.47	14.37	14.00	
h	14.06	14.74	13.66	13.66	14.03	(frozen control)
	F = 3.88 (99% Significance)					
	LSD (99%) = 1.37; (95%) = 1.13					
B. Green Beans						
a	12.06	12.51	10.64	11.77	11.75	
b	12.33	11.45	11.66	10.61	11.51	
c	12.22	11.34	11.31	12.19	11.77	
d	11.38	13.11	11.91	13.16	12.39	
e	12.33	12.29	12.06	12.09	12.19	
f	12.24	12.46	12.03	11.41	12.04	
g	12.77	11.52	11.29	10.72	11.58	
h	11.31	11.31	10.84	13.60	11.77	(frozen control)
	F = 0.63 (NSD)					

TABLE 11. **Proximate Analyses of Ground Beef (Study C)**

a. Fat and Moisture

			INITIAL		DEHYDRATED				REHYDRATED	
CODE	GRIND (cm)	Proc	% Fat	% Moist. *	% Fat *	% Moist **		***	% Fat	% Moist. *
A	0.5	CD	6.8	70.8	20.8	18.9	11.8	20.9	7.2	60.8
B	0.5	CD	13.9	65.2	36.8	15.9	3.4	5.7	13.0	57.6
C	0.5	CD	20.6	60.0	53.7	2.2	7.7	18.3	15.3	56.5
D	0.5	MW	6.8	70.8	24.8	6.3	3.7	#	8.0	61.4
E	0.5	MW	13.9	65.2	36.3	21.1	11.9	8.2	12.8	56.8
F	0.5	MW	20.6	60.0	52.3	4.1	3.5	15.2	13.9	58.9
G	0.8	CD	7.8	69.7	25.4	9.6	2.2	26.5	7.7	59.4
H	0.8	CD	14.9	64.5	44.5	4.6	8.5	11.7	10.7	56.3
I	0.8	CD	22.3	58.7	56.3	5.0	6.2	11.0	15.1	53.1
J	0.8	MW	7.8	69.7	23.2	11.0	19.7	13.5	6.1	60.6
K	0.8	MW	14.9	64.5	51.7	14.7	5.6	18.0	12.1	58.3
L	0.8	MW	22.3	58.7	56.3	5.0	6.2	11.0	15.1	53.1
M	1.3	CD	7.4	70.0	27.4	3.5	1.8	28.3	7.0	58.4
N	1.3	CD	20.0	61.1	44.5	5.0	6.4	16.0	11.9	54.7
O	1.3	CD	25.6	57.0	55.8	3.4	1.3	19.6	15.2	54.2
P	1.3	MW	7.4	70.0	20.5	20.4	22.3	16.2	8.1	55.3
Q	1.3	MW	20.0	61.1	41.8	13.0	3.0	5.1	14.3	53.2
R	1.3	MW	25.6	57.0	43.1	3.8	5.2	19.6	16.5	51.4

* AOAC vacuum oven method
** radiant heating method
*** calculated from mass loss

calculated to be less than 0% due to burning of sample

TABLE 11. Proximate Analyses of Ground Beef (Study C)

b. Ratios

CODE	Protein/Fat I*	Protein/Fat D**	Protein/Fat R***	Moisture/Protein I*	Moisture/Protein D**	Moisture/Protein R***	Moisture/Fat I*	Moisture/Fat D**	Moisture/Fat R***
A	3.29	2.90	4.44	3.16	0.31	1.90	10.41	0.91	8.44
B	1.50	1.29	2.26	3.12	0.34	1.96	4.69	0.43	4.43
C	0.94	0.82	1.84	3.09	0.05	2.00	2.91	0.04	3.69
D	3.29	2.78	3.83	3.16	0.09	2.01	10.41	0.25	7.68
E	1.50	1.17	2.38	3.12	0.50	1.87	4.69	0.58	4.44
F	0.94	0.83	1.96	3.09	0.09	2.17	2.91	0.08	4.24
G	2.88	2.56	4.27	3.10	0.15	1.81	8.94	0.38	7.71
H	1.38	1.14	3.08	3.13	0.09	2.17	4.33	0.10	5.26
I	0.85	0.83	1.69	3.09	0.04	1.69	2.63	0.04	2.86
J	2.88	2.84	5.46	3.10	0.17	1.82	8.94	0.47	9.93
K	1.38	0.65	2.45	3.13	0.44	1.97	4.33	0.28	4.82
L	0.85	0.69	2.11	3.09	0.13	1.67	2.63	0.09	3.52
M	3.05	2.52	4.94	3.10	0.05	1.69	9.46	0.13	8.34
N	0.95	1.13	2.81	3.23	0.10	1.64	3.06	0.11	4.60
O	0.68	0.73	2.01	3.28	0.08	1.77	2.23	0.06	3.57
P	3.05	2.88	4.52	3.10	0.34	1.51	9.46	1.00	6.83
Q	0.95	1.08	2.27	3.23	0.29	1.64	3.06	0.31	3.72
R	0.68	1.23	1.82	3.28	0.07	1.71	2.23	0.09	3.12

* Initial
** Dehydrated
*** Rehydrated

Protein is determined by subtracting the total of the percent fat and percent moisture from 1.00

TABLE 12. Drying Rates of Ground Beef (Study C)

a. Time to remove kg of Mass

CODE	TIME (MINUTES) TO REMOVE kg OF MASS 0.11	0.23	0.34	0.45	0.57	0.68	0.79	0.91	1.02	1.14
A	45	95	165	255	350	445	550	615	710	845
B	35	75	130	195	265	350	440	515	590	700
C	40	90	150	225	320	425	500	565	650	770
D	25	45	60	75	85	100	115	150	170	215
E	25	50	60	75	90	110	130	155	185	235
F	30	50	70	90	120	150	195	240	305	365
G	40	105	185	285	385	485	590	695	860	960
H	45	85	140	205	275	370	470	610	675	775
I	55	110	170	230	290	350	435	595	680	800
J	20	35	55	70	90	115	140	175	210	260
K	20	40	65	85	110	135	160	205	245	295
L	15	35	55	70	95	115	165	200	240	305
M	50	110	165	270	385	515	640	780	850	1020
N	60	130	210	285	370	480	610	735	830	970
0	60	130	200	270	360	475	555	705	—	—
P	20	40	55	75	90	120	145	170	205	260
Q	20	40	55	75	95	120	145	175	210	240
R	20	40	55	70	90	115	130	160	195	—

* rounded to nearest 5 minutes

TABLE 12. **Drying Rates for Ground Beef (Study C) (Continued)**

b. Time to remove percent moisture

CODE	TIME (MINUTES) TO REMOVE PERCENT MOISTURE*						
	12.5	25.0	37.5	50.0	62.5	75.0	87.5
A	70	165	300	450	580	720	930
B	50	135	210	355	440	595	680
C	65	150	260	415	520	630	780
D	35	60	80	105	130	155	175
E	40	60	80	105	140	180	215
F	35	60	90	125	170	225	310
G	70	195	355	515	670	890	1100
H	65	140	235	365	525	670	815
I	70	150	225	310	390	585	690
J	30	55	90	125	180	245	320
K	35	65	100	140	195	260	365
L	20	50	70	110	160	210	290
M	80	150	305	490	680	830	1025
N	75	170	270	360	515	655	825
O	75	160	245	360	515	610	780
P	25	55	75	105	150	180	240
Q	30	50	75	100	130	170	215
R	25	45	65	85	120	160	200

* rounded to nearest 5 minutes

TABLE 12. **Drying Rates for Ground Beef (Study C) (Continued)**

c. **Time to achieve percent moisture**

CODE	TIME (MINUTES) TO ACHIEVE PERCENT MOISTURE									
	65	60	55	50	45	40	35	30	25	20
A	150	305	440	555	615	680	760	830	910	980
B	5	95	190	290	380	465	520	565	615	665
C	-	-	100	220	350	480	530	595	670	745
D	55	85	105	120	135	145	160	170	185	195
E	5	50	075	100	125	145	165	190	210	230
F	-	-	080	110	145	175	210	240	265	290
G	135	325	465	595	700	815	910	975	1040	1090
H	-	90	200	305	425	535	640	680	740	800
I	-	-	080	180	255	330	385	495	615	665
J	45	85	115	150	190	220	250	270	310	325
K	-	45	085	120	155	200	235	270	315	350
L	-	-	025	060	080	115	155	285	220	255
M	125	285	450	590	720	790	845	965	1005	1065
N	-	25	140	255	340	440	540	630	705	780
O	-	-	045	155	250	350	455	530	605	720
P	45	75	100	125	150	170	[illegible]	205	230	255
Q	-	10	45	70	95	120	140	165	185	205
R	-	-	15	45	65	85	100	125	145	160

* rounded to nearest 5 minutes

TABLE 13. Drying Times of Ground Beef (Study C)

a. Individual Data

CODE	Initial Mass kg	Initial Moist. kg	Initial Moist. %	TIME (MINUTES*) Remove 0.908 kg	Remove 75%	Achieve 30%
A	1.94	1.37	70.8	615	720	830
B	1.95	1.28	65.2	515	595	565
C	2.22	1.33	60.0	565	630	595
D	1.97	1.40	70.8	150	155	170
E	2.05	1.33	65.2	155	180	190
F	1.96	1.18	60.0	240	225	240
G	2.03	1.42	69.7	695	890	975
H	2.09	1.35	64.5	610	670	680
I	2.05	1.20	58.7	595	585	495
J	2.02	1.41	69.7	175	245	270
K	2.21	1.42	64.5	205	260	270
L	2.09	1.23	58.7	200	210	185
M	2.02	1.41	69.7	175	245	270
N	1.83	1.12	61.1	735	655	630
O	1.99	1.13	57.0	705	610	530
P	1.80	1.26	70.0	170	180	205
Q	1.93	1.18	61.1	175	170	165
R	1.90	1.09	57.0	160	160	145

* rounded to nearest 5 minutes

TABLE 13. Drying Times of Ground Beef (Study C) (Continued)

b. Summarized Data

EXPLANATION	TIME, MINUTES a. Remove 0.908 kg	b. Remove 75% of Initial Moist.	c. Achieve 30% Final Moisture
1. All data			
7% fat	431	503	569
14% fat	399	422	417
21% fat	411	403	362
0.5 cm grind	373	418	432
0.8 cm grind	413	477	479
1.3 cm grind	434	434	43[illegible]
MW	181	198	202
CD	646	687	696
2. CD data			
7% fat	697	813	923
14% fat	620	640	625
21% fat	622	608	540
0.5 cm grind	565	648	663
0.8 cm grind	633	715	717
1.3 cm grind	740	698	708
3. MW data			
7% fat	165	193	215
14% fat	178	203	208
21% fat	200	198	183
0.5 cm grind	182	187	200
0.8 cm grind	193	238	242
1.3 cm grind	168	170	165

TABLE 13. Drying Times of Ground Beef (Study C) (Continued)

c. Data Analysis

Factor	a. Remove 0.908 kg Moisture	b. Remove 75% of Initial Moisture	c. Achieve 30% Final Moisture
A. All Data			
F fat	0.42***	3.48***	5.91*
LSD - 99%	-	-	223
LSD - 95%	-	-	167
F grind	2.65***	1.14***	0.35***
F process	263.3**	220.3**	93.6**
B. CD Data			
F fat	10.7**	12.4**	24.3**
LSD - 99%	345	255	331
LSD - 95%	214	158	206
F grind	43.2**	1.2***	0.49***
LSD - 99%	34.5	-	-
LSD - 95%	21.4	-	-
C. MW Data			
F fat	0.97***	0.08***	0.37***
F grind	0.48***	8.0*	1.98***
LSD - 95%	-	91	-

* 95% significance   ** 99% significance   *** no significant difference

TABLE 14. **Quality Parameters of Ground Beef (Study C)**

a. Individual Data

		Reflectance Color					
	Rehydration	Dehydrated			Rehydrated		
CODE	Ratio	L	a*	b	L	a*	b
A	+0.59	32.04	9.03	8.74	26.89	2.74	6.13
B	+0.15	34.31	6.42	8.55	29.59	2.80	6.53
C	+0.16	36.93	7.73	9.06	30.83	2.71	6.93
D	+1.36	33.66	4.60	7.68	23.76	2.50	5.17
E	+0.30	34.28	6.80	8.06	27.68	2.65	6.76
F	+0.44	36.83	7.58	8.78	29.95	2.41	6.79
G	+0.26	32.15	7.64	7.84	25.17	2.32	5.21
H	+0.10	32.43	6.95	7.32	26.37	2.66	6.08
I	+0.10	35.46	7.33	8.55	28.02	2.92	6.52
J	+0.77	32.55	6.90	7.47	23.78	2.31	5.06
K	+0.58	31.22	6.29	7.73	24.26	2.82	6.33
L	+0.33	33.43	6.27	8.03	27.36	2.63	7.08
M	+0.17	32.17	6.86	7.64	24.56	2.41	5.27
N	+0.02	34.33	4.48	6.88	26.06	2.69	5.60
O	-0.10	36.20	6.99	8.67	26.30	2.83	5.92
P	+0.51	33.22	6.79	7.85	24.03	2.59	5.40
Q	+0.40	34.71	7.26	8.40	26.98	3.16	6.60
R	-0.04	34.42	6.92	8.24	27.05	2.47	5.26
n	2	4	4	4	4	4	4

* all values negative

TABLE 14. **Quality Parameters of Ground Beef (Study C) (Continued)**

b. Summarized Data

		Reflectance Color					
	Rehydration	Dehydrated			Rehydrated		
Explanation	Ratio	L	"a"	"b"	L	"a"	"b"
A. All Data							
7% fat	0.61	32.63	6.97	7.87	24.70	2.48	5.37
14% fat	0.26	33.54	6.37	7.83	26.82	2.79	6.32
21% fat	0.15	35.54	7.14	8.56	28.25	2.66	6.41
0.5 cm grind	0.50	34.67	7.02	8.47	28.12	2.63	6.38
0.8 cm grind	0.35	32.87	6.90	7.82	25.83	2.61	6.04
1.3 cm grind	0.16	34.17	6.55	7.95	25.83	2.69	5.67
MW	0.16	33.81	6.60	8.14	26.09	2.62	6.02
CD	0.51	34.00	7.05	8.03	27.09	2.67	6.05
B. CD Data							
7% fat	0.34	32.12	7.84	8.08	25.54	2.48	5.53
14% fat	0.09	33.69	5.95	7.58	27.34	2.71	6.07
21% fat	0.06	36.19	7.35	8.76	28 38	2.82	6.45
0.5 cm grind	0.30	34.43	7.25	8.78	29.10	2.75	6.53
0.8 cm grind	0.15	33.35	7.31	7.90	26.52	2.63	5.93
1.3 cm grind	0.03	34.23	6.11	7.73	25.64	2.64	5.59
C. MW Data							
7% fat	0.88	33.14	6.09	7.67	23.86	2.47	5.21
14% fat	0.42	33.40	6.78	8.06	26.31	2.88	6.56
21% fat	0.24	34.89	6.92	8.35	28.12	2.50	6.37
0.5 cm grind	0.70	34.92	6.32	8.17	27.13	2.52	6.24
0.8 cm grind	0.56	32.40	6.49	7.75	25.13	2.59	6.16
1.3 cm grind	0.29	34.12	6.99	8.17	26.02	2.74	5.75

TABLE 14. Quality Parameters of Ground Beef (Study C) (Continued)

c. Data Analysis

		Reflectance Color					
	Rehydration	Dehydrated			Rehydated		
Explantion	Ratio	L	"a"	"b"	L	"a"	"b"
A. All Data							
F all points	54.0**	2.4**	1.8***	0.5***	3.9	1 6***	5 0***
LSD - 99%	0.30	6.46	–	–	6.39	–	–
LSD - 95%	0,25	5.59	–	–	5.53	–	–
F fat	21.3**	11.7**	1.3***	5,4**	9.3**	4 7*	17.0**
LSD - 99%	0.22	1.86	–	0.75	2.58	–	0.13
LSD - 95%	0.17	1.47	0.59	0.59	2.24	0.38	0.10
F grind	10.5**	4.6*	0.5***	3 9*	17.0**	0.3***	6.5**
LS[illegible] 99%	0.22	–	–	–	2.58	–	0.13
L[illegible] 95%	0.17	1.47	–	0.59	2.24	–	0.10
F process	34 9**	0.1***	1.2***	0.3***	0.1***	0.5***	0.0***
B. CD Data							
F fat	31.0**	11.1**	13.2**	5.5**	6.2*	1.3***	9.9**
LSD - 99%	0.11	4.79	1.20	1.12	–	–	0.65
LSD - 95%	0.09	2.15	0.94	0.88	2.00	–	0.51
F grind	39.5**	0.9***	9.7**	5.0*	9.9**	0.2***	10.4**
LSD - 99%	0.11	–	1.20	–	2.55	–	0.65
LSD - 95%	0.09	–	0.94	0.99	2.00	–	0.51
C. MW Data							
F fat	13.0**	2 50***	2.50***	2.34***	5.1*	3.5*	10.1**
LSD - 99%	0.26	–	–	–	–	–	1.03
LSD - 95%	0.20	–	–	–	2.23	0.41	0.80
F grind	32.5**	4.6*	1.5***	1.2***	2.4***	0.9***	1.3***
LSD - 99%	0.26	–	–	–	–	–	–
LSD - 95%	0.20	2.10	–	–	–	–	–

* 95% significance   ** 99% significance   *** no significant differenc

TABLE 15 Data Combinations for Analysis

COMBINATION	POWER Watts	PRODUCT
1	0	Peas
2	0	Beans
3	0	Peas and Beans combined
4	250	Peas
5	250	Beans
6	250	Peas and Beans combined
7	500	Peas
8	500	Beans
9	500	Peas and Beans combined
10	250 and 500 combined	Peas
11	250 and 500 combined	Beans
12	250 and 500 combined	Peas and Beans combined

TABLE 16. Moisture Loss as a Function of Position (Study D)
A. MW

Position	Percent Loss as Deviation from Mean (per run and Phase)				
	a*	b2*	c1*	d2*	e1*
A. Peas					
1A	-0.45	-1.44	-0.32	-2.09	-0.39
2A	-1.50	-0.12	-0.27	-0.05	-0.14
3A	+0.80	-1.78	-0.57	-1.12	+1.16
4A	-2.00	+1.26	+0.48	-0.37	+2.06
1B	-0.70	-1.11	-0.37	-1.03	+1.56
2B	+0.10	-2.02	+1.03	-0.13	+0.96
3B	+0.85	+2.41	-0.82	+2.20	+2.11
4B	+0.70	+2.60	+1.53	+3.21	-2.79
1C	-0.70	+0.52	+0.63	+0.68	+1.16
2C	-1.10	-0.54	-1.82	-2.16	+1.56
3C	-0.65	+1.34	-0.77	+1.10	-3.49
4C	+0.60	-1.10	+1.23	-0.22	-2.74
Mean	70.05	45.34	43.47	39.90	43.39
B. Green Beans					
1A	-0.75	-0.93	-0.25	-3.64	-1.92
2A	-0.43	-1.37	-2.35	-2.22	-0.62
3A	-0.24	+0.03	-2.40	-0.58	+0.68
4A	+0.50	+2.55	-1.80	+3.18	+0.38
1B	+0.71	+0.16	-0.10	-1.21	+0.08
2B	+0.63	+1.17	-0.15	-0.27	-0.07
4B	+0.68	-0.97	-0.20	+0.47	+2.18
1C	-1.32	-1.93	+3.00	+3.76	-0.22
2C	+0.34	+0.35	+2.85	+0.29	-1.82
3C	-0.10	+0.61	+0.40	+1.92	-0.02
4C	-0.61	-1.14	+0.65	-1.94	+0.88
Mean	90.18	76.20	53.20	66.20	57.32

TABLE 16. Moisture Loss as a Function of Poistion (Study D) (Continued)
B. MW

Position	% Loss as Deviation from Mean (Per Run and Phase)					
	b1*	c2*	d1*	e2*	f*	g*
A. Peas						
1A	-4.03	-5.46	-0.80	-4.98	-2.87	+0.43
2A	+0.57	+0.83	+5.80	+1.31	+1.13	+4.28
3A	-4.93	-4.43	-5.15	-3.95	-4.47	-2.02
4A	+1.22	-1.96	-0.90	-1.48	+0.98	-0.52
1B	-1.33	-3.39	-1.80	-2.90	+0.08	-4.97
2B	+1.42	+2.67	-3.85	+3.15	-0.92	-0.27
3B	+2.82	+0.77	-2.30	+1.25	+2.53	+1.73
4B	+0.42	-0.12	+0.60	+0.37	+0.93	-0.62
1C	+4.82	+3.48	+9.35	+3.96	+3.03	+3.13
2C	- 2.28	-0.45	-3.00	+0.03	-3.37	-1.62
3C	+1.52	-1.71	+3.80	- 1.23	+0.88	+0.83
4C	- 0.18	+9.76	+0.70	+4.43	+2.08	-0.42
Mean	45.03	50.84	47.90	50.36	73.97	69.37
B. Green Beans						
1A	-2.55	-3.64	-4.10	-1.23	-0 .32	-0.50
2A	-2.35	-2.22	+0.85	-2.76	-0.88	-0 .85
3A	+2.25	-0.58	-2.15	-1.21	+1.02	-2.15
4A	+2.45	+3.18	+0.60	-1.01	-0 . 12	-1.35
1B	- 0.75	-1.21	-0.55	-0.24	+0.72	+0.30
2B	+0.15	+0.21	+0.75	+2.54	-0 .88	+1.35
3B	-2.15	-0.27	+3.20	+1.70	-0.22	+0.85
4B	-0.95	+0.47	-1.50	+0.34	+1.08	+0.85
1C	+1.85	+3.76	+1.35	+1.29	+0.02	+1.80
2C	-1.15	+0.29	+0.50	+0.13	-0.58	-0.90
3C	-0.85	+1.92	+2.60	+1.64	-0.58	+2.00
3C	+4.00	-1.94	-1.55	+0.11	+0.72	-1.40
Mean	51.90	66.20	60.70	75.19	88.48	86.35

* See Table 7 for explanation

TABLE 17. **Analysis of Drying Rate (Study D)**

A. By Position

Position	0 Watts	250 Watts	500 Watts	250 and 500 Watts combined
	Total of Deviations			
1A	-12.18	-18.88	-11.18	-30.06
2A	- 9.07	- 2.92	+ 8.63	+ 5.71
3A	- 4.02	-11.13	-16.63	-27.76
4A	+10.24	+5.74	- 4.66	+ 1.08
1B	- 1.61	- 5.87	-10.16	-16.03
2B	+ 2.33	+ 2.65	+ 3.68	+ 6.33
3B	+ 8.29	+ 3.47	+ 6.43	+ 9.90
4B	+ 7.41	+ 1.83	- 0.04	+ 1.87
1C	+ 5.56	- 16.97	+20.88	+37.85
2C	- 3.05	- 7.54	- 6.12	- 13.66
3C	+ 0.34	+ 1.18	+ 9.64	+10.82
4C	- 4.39	+14.45	- 0.53	+13.92
F	0.63	3.74	4.35	7.16
Significance	NSD	99%	99%	99%
LSD	–	1.12	1.21	1.08

Table 17. Analysis of Drying Rate (Study D) (Continued)

B. By Rows and Columns

Factor	Peas	Total of Deviations Beans	Peas and Beans
A. 0 watts			
Row A	- 2.85	-12.18	-15.03
Row B	+10.29	+ 6.13	-16.42
Row C	- 7.47	+ 5.95	- 1.42
Column 1	- 4.05	- 4.16	- 8.21
Column 2	- 7.20	- 2.59	- 9.79
Column 3	+ 2.77	+ 1.84	+ 4.61
Column 4	+ 8.45	+ 4.81	+13.26
F row	2.23	2.77	3.22
significance	NSD	NSD	95%
LSD	-	-	1.06
F Column	1.72	0.56	2.07
significance	NSD	NSD	NSD
B. 250 watts			
Row A	-23.42	- 3.77	-27.19
Row B	+ 5.88	- 3.80	+ 2.08
Row C	+17.48	+ 7.48	+25.05
Column 1	- 5.67	- 2.11	- 7.78
Column 2	- 0.40	- 7.41	- 7.81
Column 3	- 7.02	+ 0.53	- 6.48
Column 4	+13.13	+ 8.89	+22.02
F row	0.81	1.47	5.42
significance	NSD	NSD	95%
LSD	-	-	2.31
F column	1.23	3.86	2,27
significance	NSD	95%	NSD
LSD	-	1.99	-

TABLE 17. Analysis of Drying Rate (Study D) (Continued)

Factor	Peas	Beans	Peas and Beans Combined
C. 500 watts			
Row A	- 7.98	-15.86	-23.84
Row B	- 9.61	+ 9.60	- 0.01
Row C	+17.56	+ 6.31	+23.87
Column 1	+ 1.42	- 1.88	- 0.46
Column 2	+ 5.83	+ 0.36	+ 6.19
Column 3	- 7.04	+ 6.48	- 0.56
Column 4	+ 0.21	+ 4.92	+ 5.17
F row	2.42	8.03	3.84
signfificance	NSD	99%	95%
LSD	-	1.41	1.79
F column	3.56	0.52	0.20
significance	95%	NSD	NSD
LSD	3.87	-	-
D. 250 + 500 watts combined			
Row A	- 31.40	-19.63	- 51.03
Row B	- 3.73	+ 5.80	+ 2.07
Row C	+23.87	+13.79	+48.93
Column 1	- 4.25	- 3.99	- 8.24
Column 2	+ 5.43	- 7.05	- 1.62
Column 3	- 14.06	+ 7.02	- 7.03
Column 4	+ 12.89	+ 3.98	+ 16.87
F row	5.28	4.92	9.16
significance	99%	99%	99%
LSD	4.21	2.20	4.45
F column	0.86	0.93	0.66
significance	NSD	NSD	NSD
LSD	-	-	-

APPENDIX -
PERCENT MOISTURE AS A FUNCTION OF DRYING TIME - PEAS

Mass, kg	3.0	3.0	3.0	3.0	4.0	4.0	4.0	4.0	5.0	5.0*	5.0	5.0
Power, KW	0.00	0.25	0.50	0.75	0.00	0.25	0.50	0.75	0.00	0.25	0.50	0.75
Time, min	Percent Moisture											
15	72.8	73.6	72.4	72.7	74.4	70.9	73.3	73.6	74.5	72.3	72.3	72.8
30	71.9	72.3	70.5	71.2	71.8	73.4	69.8	72.4	72.8	73.4	71.2	71.4
45	70.8	70.7	68.1	68.6	70.9	72.3	68.1	70.6	72.1	72.6	69.9	69.9
60	69.6	68.9	65.4	65.8	70.1	71.1	66.4	68.4	71.4	71.8	68.4	68.3
75	68.4	66.9	62.5	62.2	69.2	69.8	64.3	65.9j	70.7	71.1	66.8	66.9
90	67.0	64.9	59.0	58.0	68.2	68.4	62.0	62.8	69.8	70.3	65.1	64.6
105	65.6	63.1	54.7	53.6	67.1	64.2	59.4	57.8	69.0	68.9	63.3	62.4
120	64.1	60.2	50.2	48.0	66.1	63.5	56.6	56.0	68.1	67.6	61.2	60.0
135	62.6	57.3	45.2	40.7	65.0	62.4	53.5	52.5	67.2	67.3	58.9	57.3
150	61.0	54.2	39.6	32.9	63.8	61.5	49.8	44.5	66.3	66.9	56.3	54.1
165	59.3	50.7	36.6	25.0	62.5	59.4	46.0	40.0	65.3	66.5	53.6	50.1
180	57.4	47.1	28.2	18.4	61.2	57.1	41.7	33.2	64.4	65.6	50.3	45.8
195	55.4	42.8	20.9	12.1	59.8	54/6	37.0	24.9	63.3	63.7	46.5	40.2
210	53.0	38.1	14.3	6.4	58.3	51.9	32.3	18.7	62.3	60.7	42.3	34.1
225	50.6	33.6	8.9	5.6	56.9	49.0	27.2	16.1	61.3	56.0	37.5	27.9
240	48.0	28.8	5.6	2.9	55.2	46.0	21.7	8.8	60.1	52.1	32.5	22.6
255	45.3	23.3	3.4		53.5	42.3	16.7	6.3	59.0	45.6	27.0	16.4
270	42.1	18.2	1.9		51.9	38.6	11.9	4.3	57.8	40.3	22.4	13.0
285	38.7	13.9			50.0	34.9	8.3	2.9	56.7	34.8	16.5	10.2
300	35.0	10.8			47.9	30.6	5.5		55.2	28.8	9.5	7.7
315	31.2	7.5			45.9	25.7	4.3		53.5	24.6	5.3	6.1
330	27.5	4.8			43.9	21.1	3.1		51.9	15.1	1.2	4.5
345	23.9	3.9			41.8	17.0	2.5		50.2	14.6		3.4
360	20.4				39.7	13.6	2.0		48.3			
375	16.1				37.6	10.1			46.4			
390	12.6				35.2	8.1			44.6			
405	10.4				33.0	6.2			42.5			
420	8.9				30.7	5.5			40.2			
435	7.3				28.1	4.9			38.2			
450	6.5				25.8				36.3			
465					23.3				34.5			
480					21.1				32.7			
495					19.3				30.7			
510					16.9				29.2			
525					15.9				27.3			
540					14.3				25.7			
555					12.7				23.6			
570									21.9			
585									20.3			
600									18.7			
615									17.1			
630									15.8			
645									14.5			
660									13.2			
675									12.7			

* Values in this column are estimated